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# A global database of paired leaf nitrogen and phosphorus concentrations of terrestrial plants

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Abstract: Nitrogen (N) and phosphorus (P) are essential components of the basic cell structure of plants. In particular, leaf N and P concentrations and their stoichiometric relationship largely determine the photosynthesis, growth, reproduction, and ecophysiological processes of plants. As important leaf functional traits, leaf N and P concentrations and their stoichiometric relationship play vital roles in indicating plant nutrient-use strategies and their evolution in terrestrial ecosystems. They also influence physiological and ecological processes in leaves (e.g., growth rate and energy metabolism) and productivity (e.g., net primary production and net ecosystem production) at ecosystem level. However, the lack of a comprehensive data set containing paired leaf N and P concentration records has distinctly limited research on nutrient stoichiometry and leaf functional traits. Here, we provide a global database of paired records of leaf N and P concentrations. A total of 11,354 individual records were acquired spanning 1,291 sites worldwide, including 201 families, 1,265 genera, and 3,227 species. The records span a latitudinal range of 45.28 °S to 68.35 °N and a longitudinal range of 155.5 °W to 168.0 °E. The variables provided for each individual record are (1) geographical location (longitude, latitude, and altitude); (2) matched leaf N and P concentrations and N:P ratio; (3) taxonomic information (family, genera, and species); (4) life form (angiosperm/gymnosperm, monocotyledonous/dicotyledonous and woody plants/herbaceous plants; note that woody plants were further divided into coniferous, deciduous broad-leaved, and evergreen broad-leaved woody species and that herbaceous plants were further divided into annual and perennial species); (5) mean annual temperature (MAT) and mean annual precipitation (MAP); and (6) soil N and P concentrations and pH value in some records. To date, this database is the world's largest database of paired leaf N and P concentrations, which contains matched information of geographical location, environmental factors, and taxa. We believe that the database will play a fundamental and crucial part of ecological stoichiometric studies. There are no copyright restrictions. When using this database, we kindly request that you cite this article, respecting all the authors' hard work during sample collection and data compilation.

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# A global database of paired leaf nitrogen and phosphorus concentrations of terrestrial plants

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**ABSTRACT.** Nitrogen (N) and phosphorus (P) are essential components of the basic cell structure of plants. In particular, leaf N and P concentrations and their stoichiometric relationship largely determine the photosynthesis, growth, reproduction and eco-physiological processes of plants. As important leaf functional traits, leaf N and P concentrations and their stoichiometric relationship play vital roles in indicating plant nutrient-use strategies and their evolution in terrestrial ecosystems. They also influence physiological and ecological processes in leaves (e.g., growth rate and energy metabolism) and at ecosystem level N or P affect productivity. However, the lack of a comprehensive dataset containing paired leaf N and P concentration records has distinctly limited research on nutrient stoichiometry and leaf functional traits. Here, we provide a global database of paired records of leaf N and P concentrations. A total of 11,354 individual records were acquired spanning 1,291 sites worldwide, including 201 families, 1,265 genera and 3,227 species. The records span a latitude range from 45.28°S to 68.35°N and a longitude range from 155.5°W to 168°E. The variables provided for each individual record are: (1) geographical location (longitude, latitude and altitude); (2) matched leaf N and P concentrations and N:P ratio; (3) taxonomic information (family, genera and species); (4) life form (angiosperm/gymnosperm, monocotyledonous/dicotyledonous and woody plants/herbaceous plants with woody plants further divided into coniferous, deciduous broad-leaved and evergreen broad-leaved woody species and herbaceous plants further divided into annual and perennial species); (5) mean annual temperature and mean annual precipitation; and (6) soil N and P concentrations and pH (partly). Up to now, this database is the world's largest database of matched leaf N and P concentrations, which contains matched information of geographical location, environmental factors, and taxa. We believe that the database will play a fundamental and crucial part in ecological stoichiometric studies. When using this database, we kindly request that you cite this article, respecting all the authors' hard work during sample collection and data compilation.

**KEY WORDS:** *leaf; nitrogen; N:P ratio; phosphorus; plant functional group; stoichiometry; scaling exponent; terrestrial plants.*

## INTRODUCTION

At least 17 basic elements are needed for plants to grow, among which nitrogen (N) and phosphorus (P) are essential components of the basic cell structure of plants and play pivotal roles in the synthesis and transformation of protein, nucleic acids, ATP, ADP and NADP (Garten, 1976). Concentrations of N and P in plants and their balance influence not only individual plants but also the whole ecosystem, including plant growth and ecosystem productivity (Chapin et al., 1986; Sardans et al., 2012; Sullivan et al., 2014), decomposition and transformation of dead plant material, nutrient utilization and activity of symbiotic microorganisms (Treseder, 2004; Sundqvist et al., 2014), maintenance of species reproduction and diversity (Fujita et al., 2014), nutrient cycling (Asner et al., 1997), feeding by herbivores (Elser et al., 2000), energy flow and ecosystem succession (Magill et al., 2004). Especially for the leaves, the N to P stoichiometric relationship havs a great influence on metabolic activities, photosynthesis and primary production of the individual plants. Therefore, leaf N and P concentrations and their stoichiometric relationships have become the focus of stoichiometry studies in plants (Sterner and Elser, 2002; Kerkhoff et al., 2006; Sardans et al., 2012).

Leaf N and P stoichiometric characteristics include N and P concentrations, N:P ratios, and N~P scaling relationships. As fundamental properties of the leaf economics spectrum (LES), leaf N and P concentrations show a strong correlation an can be used for models of relative growth rate and energy metabolism in plants (Wright et al., 2004). Empirical values of N:P ratios are often applied to indicate N or P limitation in ecosystems (Koerselman & Meuleman 1996; Güsewell, 2004). However, how does the leaf N to P stoichiometric relationship vary between regions, climates, life forms, species and other modifying variable? Understanding such variation will increase the accuracy of models and predictions about plant growth and ecosystem functioning

(Messier et al., 2016; Yan et al., 2017; He et al., 2018). Theoretically, the leaf N to P stoichiometric relationship reflects the adaptation of plants to their environment. During the process of evolution, plants developed their own mechanisms of nutrient uptake, which allows them to absorb and accumulate nutrients selectively to maintain the homeostasis of intracellular nutrient concentrations and keep a relatively constant ratio between concentrations of diverse nutrients among plant cells (Garten 1976; Sterner and Elser, 2002). Therefore, plant stoichiometric characteristics can be used as an important feature or functional trait of plant individuals and entire plant communities, highlighting different acclimations and adaptations of plants to their environment and ultimately their physiological and ecological strategies together with underlying phylogenetic processes (Kerkhoff et al., 2006; Ågren 2008; Brulheide et al., 2018).

Based on different species, communities, ecosystems and global databases, previous researchers obtained a series of widely dissimilar values of leaf N and P stoichiometric characteristics (Wright et al., 2005; McGroddy et al., 2004; Kerkhoff et al., 2006; Reich et al., 2010). This included divergent patterns of leaf N and P stoichiometric relationships along latitudinal, altitudinal and other gradients (Reich et al., 2004; Niklas et al., 2006; Zhao et al., 2016; Tian et al., 2018). It also indicated that different species, functional groups, life histories, environmental conditions (including climate factors) had complex impacts on the N to P stoichiometric relationship (Zhang et al., 2012; Yang et al., 2019). Consequently, the same plants in different regions may show significantly different N to P stoichiometric relationships, while different plant species in the same region may show similar N and P stoichiometric relationships. In order to examine such variations and the underlying driving factors, it is necessary to conduct comprehensive analyses for plants across different regions, climatic zones, taxonomic groups, life forms and other contrasts.

Nevertheless, further exploration of leaf N and P stoichiometric relationships have been hampered by the lack of data availability across large scales. For example, in the global database of Wright et al. (2005), only 745 records of leaf N and P (based on leaf-mass units) were available to analyze leaf N~P scaling relationships. Moreover, only countable records of N and P concentrations fell into plants from different ecosystem types including temperate forest, rainforest (Hawaii), tropical forest, tundra, wetland, alpine vegetation, and grassland. The data set of McGroddy et al. (2004) only contained three types of woody plants with 55 records located across a latitudinal range from 23.5°S to 23.5°N. Niklas et al. (2005) used data from 131 vascular plants (53 monocotyledonous species and 78 dicotyledonous species) to explore the relationships between leaf N to P stochiometry and plant growth. Databases developed by Reich et al. (2004) and Reich et al. (2010) were incompletely open to the public, and the portions uploaded to the TRY database did not show matched geographical information on latitude, longitude and altitude. In summary, the completeness, uniformity and credibility of previous studies were compromised in several ways.

Considering the actual requirements and the progresses of global information about plant traits and ecosystem functioning in macroecology and biogeography (He et al., 2018), we built a comprehensive database containing an unprecedented number of records of matched leaf N and P concentrations. We combined data from the TRY-Plant Data (ref. needed here!!) and own data from large standardized field campaigns. We believe that our new database provides rich and detailed information to support research about global patterns of plant functional traits in the future. In our database we include only those records of paired N and P concentrations that come from fully developed green leaves with detailed location information. In total, 4,213 records in our database are taken from the TRY database (https://www.try-db.org) with specific location information; and 7,141 records come from published literature or own field data from trees, shrubs and herbs in China. Duplicate records were carefully removed. Field sampling was primarily completed from July to August in the years 2000–2016. Leaf samples were dried at 60 °C for 72 h and ground in a ball mill (NM200, Retsch, Haan, Germany), and then their total N and P concentrations were measured by the Dumas combustion method using an elemental analyser (Elementar vario EL III, Elementar, Hanau, Germany; Jones, 2001). The database eventually included 11,354 records, covering 201 families, 1,265 genera, and 3,227 species. All records were derived from natural ecosystems, while ecosystems affected by fertilization or plants cultivated in the greenhouse or plantations were excluded. Life forms were divided into woody plants (coniferous, deciduous broad-leaved and evergreen broad-leaved woody species), shrubs (subshrubs), vines, herbaceous plants (annual or perennial) and ferns.

Because of standardized sampling methods, large number of records and wide spatial distribution, our database can provide comprehensive material for the study of leaf functional traits and for testing theoretical assumptions about an important ecological stoichiometric relationship, namely between leaf N and P concentrations. Furthermore, the database contains information that can help to understand nutrient cycling in ecosystems and the construction of biogeochemical models under global change.

## METADATA

### *CLASS I. DATA SET DESCRIPTORS*

**A. Data set identity:** A global database of paired leaf nitrogen and phosphorus concentrations of terrestrial plants

**B. Data set and metadata identification codes:** Global_Leaf_nitrogen_phosphorus_concentrations.csv

## C. Data set description

### 1. Originators

Di Tian[1], Jens Kattge[2], Yahan Chen[3], Wenxuan Han[4], Yongkai Luo[3], Jinsheng He[5], Huifeng Hu[3], Zhiyao Tang[5], Suhui Ma[5], Zhengbing Yan[5], Quanhong Lin[1], Bernhard Schmid[6], Jingyun Fang[5]

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### 2. Abstract

Nitrogen (N) and phosphorus (P) are essential components of the basic cell structure of plants. In particular, leaf N and P concentrations and their stoichiometric relationship largely determine the photosynthesis, growth, reproduction and eco-physiological processes of plants. As important leaf functional traits, leaf N and P concentrations and their stoichiometric relationship play vital roles in indicating plant nutrient-use strategies and their evolution in terrestrial ecosystems. They also influence physiological and ecological processes in leaves (e.g., growth rate and energy metabolism) and at ecosystem level N or P affect productivity. However, the lack of a comprehensive dataset containing matched leaf N and P concentration records has distinctly limited research on nutrient stoichiometry and leaf functional traits. Here, we provide a global database of paired records of leaf N and P concentrations. A total of 11,354 individual records were acquired spanning 1,291 sites worldwide, including 201 families, 1,265 genera and 3,227 species. The records span a latitude range from 45.28°S to 68.35°N and a longitude range from 155.5°W to 168°E. The variables provided for each individual record are: (1) geographical location (longitude, latitude and altitude); (2) matched leaf N and P concentrations and N:P ratio; (3) taxonomic information (family, genera and species); (4) life form (angiosperm/gymnosperm, monocotyledonous/dicotyledonous and woody plants/herbaceous plants with woody plants further divided into coniferous, deciduous broad-leaved and evergreen broad-leaved woody species and herbaceous plants further divided into annual and perennial species); (5) mean annual temperature and mean annual precipitation; and (6) soil N and P concentrations and pH (partly). Up to now, this database is the world's largest database of matched leaf N and P concentrations, which contains matched information of geographical locations, environmental factors, and taxa. We believe that the database will play a fundamental and crucial part in ecological stoichiometric studies. When using this database, we kindly request that you cite this article, respecting all the authors' hard work during sample collection and data compilation.

**3. Key words:** *leaf, nitrogen, N:P ratio, phosphorus, plant functional group, stoichiometry, scaling exponent, terrestrial plants*

## *CLASS II. RESEARCH ORIGIN DESCRIPTORS*

### A. Overall project description

**1. Identity:** A global database of paired leaf nitrogen and phosphorus concentrations of terrestrial plants

**2. Originators:** J.Y. Fang, D. Tian, J. Kattge, W.X. Han, Y.H. Chen, Y.K Luo, H.F Hu, Z.Y. Tang, J.S. He, S.H. Ma, Z.B. Yan, Q.H. Lin, B. Schmid

**3. Period of study:** Field sampling was conducted during 2000–2016. The database was compiled between 2015 and 2018.

**4. Objectives:** (i) To document global variation in leaf nitrogen and phosphorus concentrations of terrestrial plants and examine leaf N and P stoichiometric relationships among different life forms, phylogenetic taxa, biomes, plant communities and sites; and (ii) to provide a broad-scale comprehensive dataset for verifying important leaf functional traits and classic theories in plant ecological stoichiometry across individual, species, genus, family, community, ecological biomes and global scales.

**5. Sources of funding:** This work was supported by the National Natural Science Foundation of China (grant no. 31800397, 31321061 and 31330012), National Key R&D Program of China (grant no. 2017YFC0503900) and the TRY initiative on plant traits (http://www.try-db.org). The TRY database is hosted at the Max Planck Institute for Biogeochemistry (Jena, Germany) and supported by DIVERSITAS/Future Earth, the German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig and EU project BACI [grant ID 640176].

## B. Specific subproject description

### 1. Data sources

The dataset was partly compiled from an open data source (i.e. the TRY-Plant Trait Database, https://www.try-db.org/TryWeb/Data.php; Kattge et al., 2011), an integrated data set of China established by Han et al. (2005) and four major original sampling studies (He et al., 2008; Chen et al., 2013; Yang et al., 2016; Luo, 2017 *unpublished*).

We collected only those paired records of N and P concentrations in green leaves with detailed location information and excluded other records without site information or with unpaired N-P records. Specifically, the sub-datasets in TRY-Plant Trait Database were carefully compiled: Abisko & Sheffield Database (ID1, Quested et al., 2003), GLOPNET-Global Plant Trait Network Database (ID20, Wright et al., 2004), The RAINFOR Plant Trait Database (ID34, Fyllas et al., 2009), Sheffield Database (ID37, Cornelissen et al., 2003), The VISTA Plant Trait Database (ID45, Garnier et al., 2007), Leaf and Whole Plant Traits Database (ID50, Kazakou et al., 2006), Tropical Plant Traits From Borneo Database (ID51, Swaine, 2007), Wetland Dunes Database (ID56, Bakker et al., 2005), Global Leaf Robustness and Physiology Database (ID87, Niinemets, 2001), The Netherlands Plant Traits Database (ID88, Ordonez et al., 2010), Ukraine Wetlands Plant Traits Database (ID90, van Bodegom, *unpublished*), Global A, N, P, SLA Database (ID94, Reich et al., 2009), Traits from Subarctic Plant Species Database (ID105, Freschet et al., 2010), Global $^{15}N$ Database (ID130, Craine et al., 2005), Functional Traits of Graminoids in Semi-Arid Steppes Database (ID152, Adler et al., 2004), Traits of Hemiparastic Plants (ID166, Demey et al., 2013) and Plant Traits for Pinus and Juniperus Forests in Arizona (ID193, Laughlin et al., 2011).

In Han et al. (2005), 2,094 records of paired leaf N and P concentrations from 127 sampling sites across China were collected from published literature. Among these records, 1,979 were incorporated into the current database because they contained detailed taxonomic information about family, genus and species. The other data from four major original studies (He et al., 2008; Chen et al., 2013; Yang et al., 2016; Luo, 2017 *unpublished*) were sampled using standardized collection protocols in the summer (see details in **Experimental Design and Research Method**).

## 2. Site description

**a. Sites and Geography**

Sites include natural forest, grassland, shrubland and wetland ecosystems across the globe. The terrestrial sites include the following continents: Asia, Africa, Europe, Oceania (including Hawaii) and America (North America, Central America and South America). In total, coverage includes boreal, temperate and tropical ecosystems except Antarctica.

**b. Habitat**

These sites cover a wide array of natural habitats from humid tropical forests to boreal forests, arid, semi-arid grasslands, shrublands and alpine ecosystems. The typical vegetation types include desert, scrub, steppe, meadow, shrublands, boreal forests, temperate deciduous forests, subtropical and tropical evergreen forests, as well as wetlands.

**c. Geology**

Sites include terrestrial sites scattered across the globe and therefore present various geological formations. For example, data from Hawaii cover old and young site ages and thus soil developmental stages along a chronosequence.

**d. Site history**

All sites are in natural ecosystems without or with weak anthropogenic influences. Greenhouse cultivations and artificial plantations are not included in the database.

**e. Climate**

Climate ranges from boreal, temperate to tropical regions with substantial annual variations in both temperature and rainfall. For example, mean annual temperature ranges across observations from –11.4 to 27.8 °C and mean annual precipitation ranges from 17 to 3922 mm.

## 3. Experimental design

Leaf samples from forests (Chen et al., 2013), shrublands (Yang et al., 2016; Luo, 2017) and grasslands (He et al., 2006, 2008; Geng et al., 2017) across China were collected in summer from 2000 to 2016. In these natural ecosystems, plots were selected according to the vegetation of local sites and then at least 5 fully expanded sun leaves of plant individuals of each species in the plots were collected and oven-dried at 60 °C in the laboratory. After being grounded in ball mills (NM200, Retsch, Haan, Germany), the powder of leaf samples was used to measure leaf N concentrations with an elemental analyzer (2400 II CHNS/O Elemental Analyzer, Perkin-Elmer, USA) with a combustion temperature of 950 °C and a reduction temperature of 640 °C. Leaf P concentrations were determined with the molybdate/ascorbic acid method after $H_2SO_4$-$HClO_4$ digestion (Jones, 2001). The absorbance of each sample for P concentration detection was measured at 700 nm after 20 min of adding molybdenum-stibium-ascorbic acid reagent (Jones, 2001).

Soil samples at 0–10 cm depth in forests were taken in plots where the leaf samples were sampled. Three to five soil cores in each plot were randomly collected and mixed evenly. Then soil total N and P concentrations were detected through air-drying, sieving and elemental analyzer similar to the measurement processes of leaf N and P concentrations. The average values of soil N and P concentrations in three plots at the same site were used to represent the soil N and P concentrations of local plant species (Chen et al., 2013). In shrublands and grasslands, subsamples from three pits at 0–10 cm depth were mixed and detected. Soil pH was measured in water suspension with a 1:2.5 soil:water ratio using a benchtop pH meter (SevenEasy Plus, Mettler Toledo, Switzerland) or in both 0.01 M $CaCl_2$ and bi-distilled $H_2O$ potentiometrically (Geng et al., 2006). The average values of soil variables from three soil subsamples near the plant samples were used to represent their corresponding soil N and P concentrations.

## 4. Research methods

The data processing involved four steps: (1) standardization of leaf N and P records and supplementary variables including matched soil N and P concentrations, soil pH and brief descriptions of their locations, (2) assignment of a consensus of family, genus and species names, (3) standardization of growth-form classification to each species, and (4) extraction of mean annual temperature (MAT) and mean annual precipitation (MAP).

For the first step, paired N and P concentrations of green leaves with detailed location information (latitude and longitude) were incorporated into the database and other records without site information or with unpaired N-P records were excluded. According to the related references with geographic information on latitude, longitude and altitude (for some records), we located the sites of each individual and checked their local vegetation types and biomes.

Then, we checked and matched the species names of each individual with standardized abbreviations removing special characters and numbers in the names. Furthermore, we used the following literature to identify plant growth forms and phylogenetic taxonomy: the Flora of China (http://frps.eflora.cn/), Angiosperm Phylogeny Website (http://www.mobot.org/MOBOT/research/APweb/) (Stevens, 2001), Useful Tropical Plants (http://tropical.theferns.info/), Wikipedia (https://en.wikipedia.org/wiki) and Australian Native Plants (https://www.anbg.gov.au/index.html). To avoid inconsistencies in plant names and classifications, the taxonomy of all records was homogenized following the Flora of China (http://frps.eflora.cn/). A plant growth form dataset for the New World established by Engelmann et al. (2016) was also used in our dataset to determine plant growth forms. All plants were assigned to one of six growth forms: ferns, herbs, subshrubs (e.g. *Artemisia* species), shrubs, trees or vines. Subsequently, the six growth forms except for subshrubs were further divided into deciduous coniferous species, deciduous broadleaved species, evergreen coniferous species, evergreen broadleaved species, dicotyledonous herbs, monocotyledonous herbs and semi-deciduous species on the basis of their morphology and physiology. Here, a small part of species with fleshy leaves, thorns and other hardly interpretable leaf types were only grouped into evergreen or deciduous species.

Finally, the climatic factors including MAT and MAP were predominately complied from the original studies. The other MAT/MAP variables not provided in the original publications were estimated through data extraction from a global climatic data set (http://worldclim.org/version2) with a resolution of 0.0083×0.0083 (*ca.* 1 $km^2$). Additionally, the corresponding data of soil total phosphorus density in the top 50 cm soil were extracted from Global Gridded Soil Phosphorus Distribution Maps (Yang et al., 2014, http://dx.doi.org/10.3334/ORNLDAAC/1223) for those compiled leaf N and P concentration records without soil nutrient content information.

**5. Project personnel**

Many people including graduate students from Peking University, workers and researchers have contributed to the development of this project, helping to take the measurements in field sampling, investigation and data compiling.

## *CLASS III. DATA SET STATUS AND ACCESSIBILITY*

**A. Status**

**1. Latest update:** May 2019.

**2. Metadata status:** Metadata are complete.

**3. Storage location and medium:** Parts of the data set are stored in raw data order at the TRY Data Portal (ID53 and ID181, contributed by Jingyun Fang and Wenxuan Han) hosted at https://www.try-db.org/de/DatasetDetails.php. The whole dataset will be stored as Supporting Information to this publication in the Ecological Society of

America's journal *Ecology.* The dataset is also available via direct access to the contact person. The dataset is also stored in non-proprietary digital form by the contact person. Electronic or paper copies of data sources (articles, reports, theses, etc.) are also available via direct access to the corresponding persons.

**B. Data verification**

The dataset has passed through several rounds of review as the data contributors have published several studies based on parts of the dataset (e.g. Han et al., 2005; Chen et al., 2013; Geng et al., 2016; Yang et al., 2016; Yan et al., 2017; Tian et al., 2018), which ensured the accuracy of the units of variables and the matching of leaf N and P concentrations and the associated variables. Moreover, the data compilers have also gone through extensive data verification by checking credible ranges and outliers of all variables in the database.

**C. Accessibility**

**1. Contact person:**

Jingyun Fang, email: jyfang@urban.pku.edu.cn; Tel/Fax: 86-10-6275 6560; Affiliation: Institute of Ecology, College of Urban and Environmental Sciences, Peking University, 5 Yiheyuan Rd., Beijing 100871, China.

Di Tian, email: tiandi@cnu.edu.cn; Tel/Fax: 86-10-6890 2374; Affiliation: College of Life Sciences, Capital Normal University, 105 West Three Ring North Rd., Beijing, 100048, China

**2. Copyright restrictions:** No copyright restrictions.

**3. Proprietary restrictions:** None. When using the dataset, we request the users to cite this paper, recognizing their use of the data in publications, research proposals, websites and other outlets.

**4. Costs:** None.

***CLASS IV: DATA STRUCTURAL DESCRIPTORS***

**A. Data set file**

**1. Identity:** Leaf_Nitrogen_and_phosphorus_concentrations_data.csv.

**2. Size:** 2.11 MB.

**3. Format:** comma-delimited plain text, no compression.

**4. Header information:** The header row indicates variable names as described in Table 1 below. The dash means that the field is not applicable to that dataset.

**Table 1.** Definitions of the variables included in the data set file “Leaf_Nitrogen_and_phosphorus_concentrations_data.csv”. The dash means that the field is not applicable to that dataset.

| Column | Variable | Variable description | Unit | Range |
|---|---|---|---|---|
| 1 | Individual_ID | Unique code identifying each individual | - | 1 ~ 11355 |
| 2 | Leaf_N | Leaf N concentration | mg $g^{-1}$ | 2.48 ~ 66.80 |
| 3 | Leaf_P | Leaf P concentration | mg $g^{-1}$ | 0.08 ~ 9.59 |
| 4 | N_P_Ratio | Leaf N:P ratio | - | 1.63 ~ 99.23 |
| 5 | Latitude | The original latitude: a negative value indicates southern latitude, while a positive value represents northern latitude | ° | -45.28 ~ 68.35 |
| 6 | Longitude | The original longitude: a negative value indicates western longitude, while a positive value represents eastern longitude | ° | -155.5 ~ 168.0 |
| 7 | Altitude | Altitude | m | -2 ~ 5249 |

| | | | | |
|---|---|---|---|---|
| 8 | Location_description | A brief description about the location of the record | - | - |
| 9 | MAT | Mean annual temperature | ºC | -11.4 ~ 27.8 |
| 10 | MAP | Mean annual precipitation | mm | 17 ~ 3922 |
| 11 | Soil_N | Soil total N concentration | mg $g^{-1}$ | 0.118 ~ 19.53 |
| 12 | Soil_P | Soil total P concentration | mg $g^{-1}$ | 0.022 ~ 3.981 |
| 13 | Soil_P_density | Soil total phosphorus density in the top 50 cm soil extracted from Global Gridded Soil Phosphorus Distribution Maps | g $m^{-2}$ | 69.00 ~ 1323.81 |
| 14 | Soil_pH | Soil pH | - | 3.3 ~ 8.9 |
| 15 | Phylum | Phylum including angiosperm, gymnosperm and fern | - | - |
| 16 | Cotyledon | Angiosperms divided into dicot, monocot and fern | - | - |
| 17 | Family_New | Family names according to Angiosperm Phylogeny Website (http://www.mobot.org/MOBOT/research/APweb/) (Stevens, 2001) | - | - |
| 18 | Family | Family names according to Flora of China (http://frps.eflora.cn/) | - | - |
| 19 | Genus | Genus name determined through taxonomic checking | - | - |

| | | | | |
|---|---|---|---|---|
| 20 | Species | Species name determined through taxonomic checking | - | - |
| 21 | Life_form1 | Assignment to life form on the basis of morphology and physiology, including ferns (Fern), herbs (H), subshrubs (Subs), shrubs (S), trees (T) and vines (V). | - | - |
| 22 | Life_form2 | Assignment to life form including deciduous coniferous species (Dc), deciduous broadleaved species (Db), evergreen coniferous species (Ec), evergreen broadleaved species (Eb), dicotyledonous herbs (Hf), monocotyledonous herbs (Hg), semi-deciduous species (Semi). A small part of species with fleshy leaves, thorns and other hardly interpretable leaf types were only distinguished to evergreen (E) or deciduous (D). | - | - |
| 23 | Leguminous | Legume (Y) or not (N) | - | - |
| 24 | dataset_name | Data sources | - | - |

## B. Data anomalies

NA in the database indicates missing data or no matching information. Some records lack the corresponding data of altitude, soil total N and P concentrations and soil pH.

## *CLASS V: SUPPLEMENTAL DESCRIPTORS*

### A. Data acquisition

#### 1. Data forms or acquisition methods

The dataset was compiled from an open data source (i.e. the TRY-Plant Trait Database, https://www.try-db.org/TryWeb/Data.php; Kattge et al. 2011), an integrated data set of China established by Han et al. (2005) and four major original sampling studies (He et al., 2008; Chen et al., 2013; Yang et al., 2016; Luo, 2017 *unpublished*) (see section II.B.1). All the records from these sub-datasets were finally integrated into one Excel sheet.

#### 2. Location of completed data forms

Some original sub-databases of our dataset can be found in the TRY-Plant Trait Database (https://www.try-db.org/TryWeb/Data.php) using Data Explorer of "ID". The completed data forms can be found through the contact person.

#### 3. Data entry verification procedures

We removed duplicated records from the data set by eye.

### B. Quality control procedures

We collected only those paired records of N and P concentrations in green leaves with detailed location information and excluded other records without site information or with unpaired N-P records. In the dataset, all the plants were distinguished to six growth forms including ferns, herbs, subshrubs, shrubs, trees and vines. A small number of species with fleshy leaves, thorns and other leaf morphology that was hard to classify into a leaf type, they were only grouped into evergreen or deciduous species without further division. The taxonomy of all records was homogenized following the Flora of China (http://frps.eflora.cn/).

**C. Related materials**

The references for data sources from TRY-Plant Trait Database (https://www.try-db.org/TryWeb/Data.php) have been introduced in section II.B.1 and listed in the section "Literature Cited".

**E. Archiving**

See the data sources in section II.B.1. The data processing was introduced in section II.B.4.

**F. Publication and results**

To better explore and interpret nutrient stoichiometry of terrestrial plants, Peking University led our field investigations and sampling across China during the past two decades. Our colleagues have published the following publications based on parts of the current data set:

Chen, Y. H., W. X. Han, L. Y. Tang, Z. Y. Tang, and J. Y. Fang. 2013. Leaf nitrogen and phosphorus concentrations of woody plants differ in responses to climate, soil and plant growth form. Ecography 36: 178-184.

Geng, Y., Z. H. Wang, C. Z. Liang, J. Y. Fang, F. Baumann, P. Kühn, T. Scholten, and J.-S. He. 2012. Effect of geographical range size on plant functional traits and the relationships between plant, soil and climate in Chinese grasslands. Global Ecology and Biogeography 21: 416-427.

Geng, Y., W. H. Ma, L. Wang, F. Baumann, P. Kühn, T. Scholten, and J.-S. He. 2017. Linking above- and belowground traits to soil and climate variables: an integrated database on China's grassland species. Ecology 98: 1471.

Guo, Y. P., X. Yang, C. Schöb, Y. X. Jiang, and Z. Y. Tang. 2017. Legume Shrubs Are More Nitrogen-Homeostatic than Non-legume Shrubs. Frontiers in Plant Science

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Tian, D., Z. B. Yan, K. J. Niklas, W. X. Han, J. Kattge, P. B. Reich, Y. K. Luo, Y. H. Chen, Z. Y. Tang, H. F. Hu, I. J. Wright, B. Schmid, and J. Y. Fang. 2018. Global leaf nitrogen and phosphorus stoichiometry and their scaling exponent. National Science Review 5: 728-739.

Yan, Z. B., P. Li, Y. H. Chen, W. X. Han, and J. Y. Fang. 2016. Nutrient allocation strategies of woody plants: an approach from the scaling of nitrogen and phosphorus between twig stems and leaves. Scientific Reports 6.

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**G. History of data set usage**

1. Data request history. None.

2. Data set update history. None.

3. Review history. None.

4. Questions and comments from secondary users. None

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